

## **PATENT OF INVENTION**

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**Method and device to assist in the piloting of an aircraft  
in a non-precision approach  
during a landing phase.**

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The present invention relates to a method and a device to assist in the piloting of an aircraft, in particular a civil transport aircraft, in a non-precision approach during a landing phase of that aircraft.

5 In the context of the present invention, the term "non-precision approach" is understood to be an approach which is not a precision instrument approach, such as for example an ILS (Instrument Landing System) type approach. It is known that, in order to use a precision instrument approach, ground stations are used which are located at the edge of the runway and at least one special radio receiver installed in the  
10 aircraft, which provides horizontal and vertical guidance before and during the landing by showing the pilot the lateral deviation with respect to an approach path and the vertical deviation with respect to a descent plan. Such a precision instrument approach provides great and effective assistance in landing (by lateral guidance and vertical guidance),  
15 particularly in poor visibility (fog, etc) or when there is no visibility.

A non-precision approach, such as considered in the present invention, therefore exists when the preceding items of information are totally or partially unavailable, such that a normal precision approach cannot be implemented.

20 In such a non-precision approach, the pilot of the aircraft must gather a plurality of items of information relating to the performance of the aircraft's navigation equipment (computers etc.) and to the integrity and precision of measurements of particular parameters, such as the position and altitude of the aircraft for example. The pilot must mentally synthesize  
25 all of this information and choose, for the landing, between:

- one of a plurality of possible assisted approach modes, for which the aircraft is provided with known means making it possible:
  - to determine a virtual approach path, in particular on the basis of information contained in a database installed in the aircraft;
  - 30 • to calculate the lateral and vertical deviations of the aircraft's position with respect to that virtual approach path; and
  - to present these deviations to the pilot.

The aircraft is then piloted in such a way as to cancel these deviations; and

- a selected approach mode, for which the pilot enters descent instructions (slope, heading, etc.) into an automatic pilot which carries out the piloting of the aircraft.

However, this obligatory mental synthesis of the various items of information increases the workload of the pilot and constitutes a significant loss of time, whilst the pilot already has to carry out many tasks at that same time for the purpose of the landing (management of communications with air traffic control, etc.).

Furthermore, the man/machine interface is different between the approach modes of an instrument approach and the approach modes of a non-precision approach, which in particular has the disadvantage of making the ergonomics of the piloting position complex.

The purpose of the present invention is to overcome these disadvantages. It relates to a method to assist the piloting of an aircraft in a non-precision approach during a landing phase.

For this purpose, according to the invention, the said method is noteworthy in that the following series of successive steps is carried out interactively and automatically:

- a) there is verified a plurality of conditions relating at least to the correct functioning of a plurality of the aircraft's equipments and to the integrity and precision of measurements of particular parameters, information coming from the said equipments and the said measurements being able to be used for the implementation of the said non-precision approach;
- b) on the basis of the said verified conditions, an appropriate approach category is selected from a plurality of different approach categories; and
- c) the approach category thus selected is presented on a display screen.

An approach category is a synthetic item of information making it possible for the pilot to appreciate the integrity, precision and availability of the items of information and the measurements that are supplied to him by the on-board equipments during the landing. Each approach category defines the approach mode or modes that are possible from among the different assisted approach modes described above during a non-precision landing.

Consequently, the degree of confidence that the pilot can have in the information provided to him varies according to the effective approach category determined by means of the invention. From an operational point of view, for the approach categories relating to reduced availability, precision or integrity, the pilot must overcome the lack of availability, precision or integrity by means of supplementary data verification actions.

Advantageously, the conditions verified in step a) comprise at least some of the following conditions:

- the correct functioning of each of the aircraft's two flight management computers;
- the correct functioning of a satellite positioning function of each of the aircraft's two multimode landing assistance receivers;
- the correct functioning of an assisted approach mode function of each of the aircraft's two multimode landing assistance receivers;
- the correct functioning of each of the aircraft's two multimode landing assistance receivers;
- the correct functioning of each of the aircraft's three inertial reference systems, integrating aerodynamic data;
- the correct functioning of an attitude and direction indicator of the aircraft;
- the integrity and precision of a position value of the aircraft;
- the uncertainty regarding this position value of the aircraft;
- the consistency between a position of the aircraft, calculated by a flight management computer of the aircraft, and a position of the aircraft received from a satellite positioning system;
- the precision of an altitude value of the aircraft; and possibly
- the correct functioning of an automatic pilot of the aircraft.

Furthermore, advantageously, in step b) a first approach category is determined when the following conditions are verified simultaneously:

- two flight management computers of the aircraft are functioning correctly;
- satellite positioning functions of two multimode landing assistance receivers of the aircraft are functioning correctly;
- at least two inertial reference systems of the aircraft, integrating aerodynamic data, are functioning correctly;

- at least one assisted approach mode function of a multimode landing assistance receiver of the aircraft is functioning correctly;
- an altitude value of the aircraft has a precision that is greater than a predetermined value;
- 5    - the integrity and precision of a position value of the aircraft are achieved; and
- a position of the aircraft, calculated by a flight management computer of the aircraft, and a position of the aircraft, received from a satellite positioning system, are consistent.

10        Furthermore, advantageously, in step b) a second approach category is determined when the following conditions are verified simultaneously:

- at least one flight management computer of the aircraft is functioning correctly;
- 15    - at least one inertial reference system of the aircraft, integrating aerodynamic data, is functioning correctly;
- at least one assisted approach mode function of a multimode landing assistance receiver of the aircraft is functioning correctly; and
- a position value of the aircraft exhibits low uncertainty.

20        Furthermore, advantageously, in step b) a third approach category is determined when the following conditions are verified simultaneously:

- at least one flight management computer of the aircraft is functioning correctly;
- at least one inertial reference system of the aircraft, integrating
- 25    aerodynamic data, is functioning correctly;
- at least one assisted approach mode function of a multimode landing assistance receiver of the aircraft is functioning correctly; and
- a position value of the aircraft exhibits high uncertainty.

30        Furthermore, advantageously, in step b) a fourth approach category is determined when at least one of the following conditions A, B, C and D is verified:

A/       two flight management computers of the aircraft are not functioning correctly;

B/       two multimode landing assistance receivers of the aircraft are not  
35        functioning correctly;

- C/ three inertial reference systems of the aircraft, integrating aerodynamic data, are not functioning correctly;
- D/ assisted approach mode functions of two multimode landing assistance receivers of the aircraft are not functioning correctly.

5       The present invention also relates to a device to assist in the piloting of an aircraft in a non-precision approach during a landing phase.

      According to the invention, this device is noteworthy in that it comprises:

- 10       - first means of verifying a plurality of conditions relating to at least the correct functioning of a plurality of equipments of the aircraft, and to the integrity and precision of measurements of particular parameters, information coming from the said equipments and the said measurements being able to be used for the implementation of the said non-precision approach;
- 15       - second means for selecting, on the basis of the said verified conditions, an appropriate approach category from among a plurality of different approach categories; and
- display means for presenting, on a display screen of the aircraft, the approach category selected by the said second means.

20       In a particular embodiment, the said display screen is a primary screen for piloting the aircraft and the said display means present the said approach category in a zone of the said primary piloting screen, which is usually used for the display of an approach category during an instrument approach.

25       The unique figure of the appended drawing will give an understanding of how the invention may be embodied. This figure is the block diagram of a device according to the invention.

      The device 1 according to the invention is intended to assist the pilot of an aircraft, in particular a civil transport aircraft, during a landing phase of the aircraft in the case of a non-precision approach.

30       According to the invention, the said device 1 which is installed in the aircraft (not shown) comprises:

- a set 2 of information sources 3A, 3B,..., 3N comprising, in particular, various equipments (computers, measuring instruments, etc.) of the
- 35       aircraft as described below;

- means 4 which are connected by a link 5 to the set 2 of information sources and which are designed to verify a plurality of conditions relating at least to the correct functioning of a plurality of the said equipments 3A,..., 3N of the aircraft, and to the integrity and measurement precision of particular parameters, made by some of these equipments 3A to 3N;
- means 6, for example an FG (Flight Guidance) computer, which are connected by a link 7 to the said means 4 and which are designed to select, on the basis of the verifications carried out by the said means 4, an appropriate approach category from among a plurality of different approach categories; and
- display means 8 which are connected by a link 9 to the means 6 and which are designed to present, on a display screen 10, the approach category selected by the said means 6.

15        Preferably, the said means 4 and 6 are integrated in a single computing unit 11.

         Furthermore, in a particular embodiment, the said display screen 10 is a usual primary piloting screen of the aircraft of the PFD (Primary Flight Display) type and the display means 8 show the said approach category in a zone 12 of the said primary piloting screen 10, which is usually used for the display of an approach category during a normal instrument approach.

         This particular embodiment has the advantage of allowing an improvement of the ergonomics for the pilot, since the latter thus has the availability of approach category information in the same location (zone 12) as used during a precision instrument approach.

         The present invention applies more particularly to an aircraft which comprises, in particular, the following information sources forming part of the said set 2:

- two flight management computers, preferably of the FMS (Flight Management System) type;
- two multimode landing assistance receivers, preferably of the MMR (Multi Mode Receiver) type, each of which comprises:
  - an FLS assisted approach mode function as described below;
  - and

- a satellite positioning function in association with a system of the GPS (Global Positioning System) type;
- three inertial reference systems integrating aerodynamic data, of the ADIRS (Air Data Inertial Reference System) type;
- 5 - an automatic pilot; and
- a flight attitude and direction indicator, which is particularly useful when the automatic pilot is not in use, that is to say in manual piloting, and which then displays piloting assistance information on the PFD primary piloting screen.

10 In a preferred embodiment, the said means 4 verify the following conditions:

- C1/ the correct functioning of each of the two FMS flight management computers;
- C2/ the correct functioning of the GPS satellite positioning function of  
15 each of the two MMR multimode landing assistance receivers;
- C3/ the correct functioning of the FLS assisted approach mode function of each of the two MMR multimode landing assistance receivers;
- C4/ the correct functioning of each of the said two MMR multimode landing assistance receivers;
- 20 C5/ the correct functioning of each of the three ADIRS inertial reference systems integrating aerodynamic data;
- C6/ the correct functioning of the flight attitude and direction indicator;
- C7/ the integrity and precision of a position value of the aircraft;
- C8/ the uncertainty regarding this position value of the aircraft;
- 25 C9/ the consistency between the position of the aircraft as calculated by an FMS flight management computer of the aircraft and a position of the aircraft as received from a GPS satellite positioning system;
- C10/ the precision of an altitude value of the aircraft; and possibly
- C11/ the correct functioning of the automatic pilot.

30 With regard to condition C7, in a particular embodiment, the FMS flight management computer calculates the position of the aircraft on the basis of values provided by the usual sources (ADIRS, GPS, VOR, DME). Furthermore, it monitors the integrity and precision of this position value. The said FMS flight management computer can calculate the position of  
35 the aircraft in different ways corresponding to the different known



navigation modes: "IRS/GPS", "IRS/DME/DME", "IRS/VOR/DME" and "IRS Only", quoted in order of decreasing precision.

In addition to the calculation of the position value, the FMS computer makes an estimation of the uncertainty regarding this position value. This  
5      uncertainty can be low or high (condition C8).

In order to verify the condition C9, the means 4 can comprise a warning computer of the FWC (Flight Warning Computer) type, which calculates the difference between the two positions, compares that difference with a predetermined value and deduces from this that the two  
10      positions are consistent only when the said difference is less than the said predetermined value.

Furthermore, regarding the condition C10:

- in a first variant, the difference between the altitude values provided by the usual two sub-computers FMS1 and FMS2 of the FMS computer is  
15      calculated; and
- in a second variant, the difference between the altitude values provided, on the one hand, by the FMS computer (FMS1 or FMS2 or both of them) and, on the other hand, by an equipment (GPS, ADIRS, radio-altimeter) which is independent of the FMS computer, is calculated.

20      In both of the preceding cases, this difference is compared with a predetermined value, and it is deduced that the altitude value is precise only when this difference is less than the said predetermined value.

In the context of the present invention, an approach category is synthetic information allowing the pilot to appreciate the integrity, precision  
25      and availability of information and measurements which are provided to him by the on-board equipments during the landing. Each approach category defines the approach mode or modes that are possible from among the different assisted approach modes, as described below, during a non-precision landing.

30      Consequently, the degree of confidence that the pilot can have in the information provided to him varies according to the effective approach category, determined by means of the invention. From an operational point of view, for the approach categories relating to a reduced availability, precision or integrity, the pilot must overcome the lack of availability,  
35      precision or integrity by supplementary data verification actions.

Thus, depending on the approach category that is presented to him (according to the present invention) on the display screen 10, the pilot chooses, for the landing, between:

- one of a plurality of possible assisted approach modes (able to be used by an FLS assisted approach mode function) for which:
  - a virtual approach path is determined, in particular with the help of information contained in a database (not shown) installed in the aircraft;
  - the lateral and vertical deviations of the position of the aircraft with respect to this virtual approach path is calculated; and
  - these deviations are presented to the pilot.

The aircraft is then piloted in such a way as to cancel these deviations; and

- a selected approach mode, for which the pilot enters descent instructions (slope, heading, etc.) into an automatic pilot which carries out the piloting of the aircraft.

In a preferred embodiment, the means 6 determine a first approach category called "F-APP", when the following conditions are verified simultaneously:

- both of the FMS flight management computers are functioning correctly;
- the GPS satellite positioning functions of the two MMR multimode landing assistance receivers are functioning correctly;
- at least two ADIRS inertial reference systems, integrating aerodynamic data, are functioning correctly;
- at least the FLS assisted approach mode function of an MMR multimode landing assistance receiver is functioning correctly;
- the altitude value of the aircraft has a precision which is greater than a predetermined value;
- the integrity and precision of a position value of the aircraft are achieved; and
- a position of the aircraft, calculated by an FMS flight management computer of the aircraft, and a position of the aircraft received by a GPS satellite positioning system are consistent.

When this first category "F-APP" is shown on the display screen 10, the pilot can choose any one of the various possible assisted approach modes.

Furthermore, the means 6 determine a second approach category 5 called "F-APP + RAW" when the following conditions are verified simultaneously:

- at least one FMS flight management computer is functioning correctly;
- at least one ADIRS inertial reference system integrating aerodynamic data is functioning correctly;
- 10 - at least the FLS assisted approach mode function of an MMR multimode landing assistance receiver is functioning correctly; and
- a position value of the aircraft has low uncertainty.

When the "F-APP + RAW" category is shown in the display screen 10, the pilot can also choose any one of the various assisted approach 15 modes but he must verify the consistency between, on the one hand, information provided by the various systems of the aircraft and, on the other hand, navigation data such as, for example, positions of ground markers, route points, etc. These items of navigation data are sometimes called "RAW data" and are shown in a normal "ND" (Navigation Display) 20 type screen.

Furthermore, the means 6 determine a third approach category called "RAW ONLY", when the following conditions are verified simultaneously:

- at least one FMS flight management computer of the aircraft is 25 functioning correctly;
- at least one ADIRS inertial reference system integrating aerodynamic data is functioning correctly;
- at least the FLS assisted approach mode function of an MMR multimode landing assistance receiver is functioning correctly; and
- 30 - a position value of the aircraft has high uncertainty.

When the "RAW ONLY" category is displayed, the pilot must preferably not use the lateral and vertical deviation information with respect to a virtual approach path, displayed in the piloting position, because a loss of precision appears in the position value. In this case, he must preferably 35 use the said navigation data ("RAW data"). Consequently, he should not

choose the assisted approach modes, which make use of the said previously mentioned deviations resulting from an FLS assisted approach mode function and he should therefore choose only the said selected approach mode. If he nevertheless chooses to use an assisted approach mode, he must then check the validity of the information used for guiding the aircraft.

Furthermore, the said means 6 can also determine a fourth approach category, when at least one of the following conditions A, B, C and D is verified:

- 10 A/ the two FMS flight management computers of the aircraft are not functioning correctly;
- B/ the two MMR multimode landing assistance receivers of the aircraft are not functioning correctly;
- 15 C/ the three ADIRS inertial reference systems of the aircraft, integrating aerodynamic data, are not functioning correctly;
- D/ the FLS assisted approach mode functions of the two MMR multimode landing assistance receivers of the aircraft are not functioning correctly.

With this fourth approach category, only a selected approach mode may be used.

The device 1 according to the present invention therefore makes it possible to reduce the workload of the pilot by presenting him, in a synthetic manner, with information (selected approach category) allowing him to choose immediately the approach mode that he will use and the way of implementing it.

In a particular embodiment, when the aircraft is in the first "F-APP" category, it retrogresses, according to the invention:

- into the second category "F-APP + RAW", when one of the following conditions is verified:
  - 30 • an FMS flight management computer is not functioning correctly;
  - the satellite positioning function of an MMR multimode landing assistance receiver is not functioning correctly;
  - the position value of the aircraft has an integrity and/or precision error and, simultaneously, the position value of the aircraft has low uncertainty;

- the altitude value is not precise;
  - the two aforesaid positions (FMS, GPS) are not consistent; and
- 5 - into the third "RAW ONLY" category, when the position value of the aircraft has an integrity and/or precision error and, simultaneously, this position value of the aircraft has a high uncertainty.

Furthermore, when the aircraft is in the second "F-APP + RAW" category, it retrogresses into the third "RAW ONLY" category when the uncertainty regarding the position of the aircraft becomes high.